AN AJSS
An Asian Journal of Soil Science
Volume 11 | Issue 1 | June, 2016 | 126-131 | e ISSN–0976–7231 ■ Visit us : www.researchjournal.co.in

Research Article

DOI : 10.15740/HAS/AJSS/11.1/126-131

Evaluating fertilizer applications on spectral behaviour of rice crop using remote sensing technique

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Received : 02.02.2016; **Revised :** 05.04.2016; **Accepted :** 01.05.2016

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Summary

Present experiments were conducted at the research farm of Indian Agricultural Research Institute, New Delhi during *Kharif* 1999 and *Kharif* 2001 to study the influence of nitrogenous fertilizer on the tilth of rice crop by remote sensing technique. Spectral radiance observations of the crop canopy were collected with the Portable Spectroradiometer which scanned from 330 nm to 1100 nm of electromagnetic spectrum range at 5nm interval (band-width). Normalized difference vegetation index was calculated for the both tillage practices, puddle and unpuddled situation at different growth stages for different fertilizer treatment. Fertilized plots were observed to have a higher value of BR than controlled ones throughout the crop growth period, both in puddled and unpuddled treatments. The higher values of band ratio were observed in puddled rice compared to the unpuddled rice irrespective of growth stages and fertilizer application levels. Statistical correlations were developed between NDVI (Normalized difference vegetation index) and RVI (Ratio vegetation index) with LAI (Leaf area index), DM (Dry matter) production and total leaf chlorophyll content. Second order polynomial equations were developed to correlate remotely sensed data with crop biometrics. Polynomial second order equations of 'band ratio' were found to be better fitted than NDVI with crop biometrics.

Key words : NDVI, Puddle, Unpuddled, Rice, Fertilizer

How to cite this article : Kumar, Shashi Bhushan, Kumar, Madhukar, Kumar, Ashok, Brajendra, Jha, B.K., Dwivedi, A.K., Ranjan, Rakesh, Kumari, Maya, Singh, Himanshu and Prasad, Pradeep (2016). Evaluating fertilizer applications on spectral behaviour of rice crop using remote sensing technique. *Asian J. Soil Sci.*, **11** (1) : 126-131 : **DOI : 10.15740/HAS/AJSS/11.1/126-131.**

Introduction

Remote sensing technique is used on large scale to monitor the crop under different stress condition. Spectral reflectance forms the basis for remote sensing. Fertilizers are vital and costly inputs in agricultural production and are used to increase the productivity of the crop. This necessitates understanding the specific requirement of the crop and strategies for their better management. Monitoring and assessing crop growth, identifying the stress conditions are extremely important to develop strategies.

Crop N status and shoot growth rate of rice were found directly related to the formation of crop components. However, N uptake rate per second was

not a reliable variable to relate to production. Until flowering, the N use efficiency for leaf biomass and specific leaf weight were constant (Stutterheim and Barbier, 1995). The sum of LAI of rice crop at the panicle differentiation stage, heading stage and 20 days after heading was positively correlated with the nitrogen rates (Lin *et al*., 1990).

Spectral resolution open up new opportunities to find characteristic spectral features related to the crop status. Considerable improvements may be expected from the extension of spectral resolution down to bandwidths of a few nanometers (Gilabert *et al*., 1996). Vegetation indices evaluated from these resolutions in the visible and infrared region, show good correlation with chlorophyll concentration, the factor most affected during crop stress.

Resource and Research Methods

The experiments were conducted at the research farm of Indian Agricultural Research Institute, New Delhi during *Kharif* 1999 and *Kharif* 2001 to study the influence of nitrogenous fertilizer on the tilth of rice crop by remote sensing technique. Rice was grown following Split Plot Design consisted of main and sub-plot in both the years. Tillage treatment was considered as main factor (puddled and unpuddled) and sub-factor was fertilizer with three replications.

Spectral observations :

Spectral radiance observation of the crop canopy were collected with the Portable Spectroradiometer, model LICOR (LI-1800). It can continuously scan from 330 nm to 1100 nm of electromagnetic spectrum range at 5nm interval (5 nm band-width). The optical system of the instrument has three major components, a filter wheel, a holographic grating monochromator and a silicon detector. Light entering the slit through the standard cosine receptor (diffuser) is directed through a filter wheel before entering the monochromator. At each scan the internal micro-computer rotates the filter wheel to select the filter for the spectral region to be scanned. The entering beam of light is dispersed by a holographic grating monochromator in the wavelength range of 330 nm to 1100 nm. The spectroradiometer has an internal microcomputer, which controls scanning, collection, reduction and storage of data. The storage capacity of this spectroradiometer is 256 kilo bytes. The spectroradiometer was connected to a computer and thus files were down loaded from the instrument and saved on soft disc.

The crop spectral reflectance, expressed in percentage, was calculated by taking ratio of measured canopy reflectance (numerator) to the incoming solar radiation. Incident radiation (standard) measurements were taken by holding the sensor horizontally with focusing it above which provided the standard value. The standard readings were taken at the beginning and at the end of each observation. Then it was averaged to get a mean value. The reflectance measurement of crop canopy was taken at 5 nm band intervals from 330 nm to 1100 nm on clear sky conditions at around solar noon local time. The sensor was held at a height of 1 m above the crop canopy with the sensor facing the crop and oriented perpendicular to the crop canopy. Precautionary measures were taken to prevent any shadow cast on the sensor element. The data collected were integrated to obtain reflectance in the following MSS (Multispectral Scanner) bands for further use in calculating different indices.

MSS 4 : 500-600 NM, MSS 5 : 600-700 NM
MSS 6 : 700-800 NM, MSS 7 : 800-1100 NM

Normalized difference vegetation index (NDVI) :

NDVI was developed by Rouse *et al*. (1973). The value lies between –1 to +1. Maximum value is expressed for healthy crop with more vegetation cover whereas the lower values expressed for stressed/poor vegetation with a low crop cover.

$$\mathbf{NDVI} = \frac{(\mathbf{NIR} - \mathbf{R})}{(\mathbf{NIR} + \mathbf{R})}$$

or $$\mathbf{NDVI} = \frac{(\mathbf{MSS\ 7 - MSS\ 5})}{(\mathbf{MSS\ 7 + MSS\ 5})}$$

Spectroradiometer was used to take spectral reflectance data. The crop spectral reflectance, expressed in percentage, was calculated by taking ratio of measured canopy reflectance (numerator) to the incoming solar radiation. Incident radiation (standard) measurements were taken by holding the sensor horizontally with focusing it above which provided the standard value. The standard readings were taken at the beginning and at the end of each observation. Then it was averaged to get a mean value. The reflectance measurement of crop canopy was taken at 5 nm band intervals from 330 nm to 1100 nm on clear sky conditions at around solar noon local time. The sensor was held at a height of 1 m above the crop canopy with the sensor facing the crop and oriented perpendicular to the crop

canopy. Precautionary measures were taken to prevent any shadow cast on the sensor element.

Band ratio (BR) or ratio vegetation index (RVI) or radiance ratio (RR) has been developed by Birth and Mc Vey (1968). It is calculated by the ratio of infrared reflectance (IR) to red reflectance (R) or reflectance in MSS 7 band to reflectance in MSS 5 band. Maximum values are expressed for healthy crop whereas low for stressed or poor crop.

$$\mathbf{BR} = \frac{\mathbf{IR}}{\mathbf{R}}$$

or, $$\mathbf{BR} = \frac{\textbf{Reflectance in MSS 7 band}}{\textbf{Reflectance in MSS 5 band}}$$

Crop biometrics :

The different crop biometrics were measured to correlate with the NDVI and BR. These indices were well correlated with green biomass, and have been used to indirectly estimate photosynthetic capacity and net primary productivity (Goward *et al.*, 1985; Sellers, 1987 and Field *et al.*, 1993) of crops. The different crop biometrics at different growth stages (phonological stages) were measured here for correlation with the spectral indices.

Research Findings and Discussion

As observed in Table 1, the highest value of NDVI were observed in puddle rice. This may be because of more healthy crop canopy due to high water holding capacity of soil (Bajpai and Tripathi, 2000). The maximum and minimum values of NDVI for puddled rice were 0.784 at 80 DAT for $N_{180}P_{60}K_{40}$ fertilizer dose and 0.260

Table 1 : NDVI changes with different growth stages of puddle and unpuddled rice (in the year 2001) using different fertilizer treatments

Treatments	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT	90 DAT	100 DAT	110 DAT
Puddled rice								
$N_0P_0K_0$	0.277	0.364	0.449	0.604	0.591	0.540	0.453	0.311
$N_{80}P_{60}K_{40}$	0.260	0.379	0.464	0.657	0.721	0.649	0.531	0.373
$N_{120}P_{60}K_{40}$	0.327	0.377	0.511	0.658	0.760	0.720	0.633	0.428
$N_{180}P_{60}K_{40}$	0.360	0.435	0.552	0.724	0.784	0.760	0.686	0.484
Unpuddled rice								
$N_0P_0K_0$	0.245	0.312	0.422	0.546	0.530	0.472	0.396	0.264
$N_{80}P_{60}K_{40}$	0.252	0.332	0.406	0.595	0.628	0.590	0.482	0.283
$N_{120}P_{60}K_{40}$	0.268	0.353	0.432	0.611	0.735	0.685	0.520	0.301
$N_{180}P_{60}K_{40}$	0.276	0.350	0.577	0.673	0.736	0.700	0.508	0.369

Table 2 : Band ratio changes with different growth stages of puddled rice (grown in the year 1999) using different fertilizer treatments

Treatments	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT	90 DAT	100 DAT	110 DAT
$N_0P_0K_0$	3.390	4.027	5.910	9.600	8.730	6.419	4.614	3.270
$N_0P_{60}K_0$	3.461	4.018	5.926	9.730	8.910	6.429	4.612	3.723
$N_0P_0K_{40}$	3.561	4.032	6.154	9.730	8.800	6.572	5.123	3.581
$N_0P_{60}K_{40}$	3.721	4.144	6.381	10.000	9.270	6.768	5.220	4.233
$N_{40}P_0K_0$	1.963	4.013	6.004	9.213	9.870	6.970	5.520	3.290
$N_{40}P_{60}K_0$	3.680	4.413	6.680	9.603	10.550	7.840	5.921	3.480
$N_{40}P_0K_{40}$	3.542	4.550	6.970	9.870	10.650	8.410	5.912	3.480
$N_{40}P_{60}K_{40}$	4.160	5.030	7.145	10.402	10.740	8.710	6.290	4.160
$N_{80}P_0K_0$	3.205	3.776	6.680	10.450	10.813	8.411	6.303	3.305
$N_{80}P_{60}K_0$	3.162	5.089	7.260	10.813	11.232	9.014	6.718	3.606
$N_{80}P_0K_{40}$	3.429	4.449	7.550	11.211	11.513	9.504	6.708	4.117
$N_{80}P_{60}K_{40}$	3.788	5.520	7.613	11.520	11.901	9.821	7.114	4.405
$N_{120}P_0K_0$	3.211	5.621	7.740	11.631	12.600	10.214	7.410	4.502
$N_{120}P_{60}K_0$	3.911	5.910	8.211	11.914	13.321	10.504	7.704	4.603
$N_{120}P_0K_{40}$	4.627	6.290	8.320	12.019	13.318	11.404	8.208	4.608
$N_{120}P_{60}K_{40}$	4.118	6.807	8.804	12.405	13.619	12.061	8.504	5.201

at 40 DAT for nutrient stressed plots ($N_{80}P_{60}K_{40}$) were observed, whereas the maximum and minimum values of NDVI for unpuddled rice were 0.736 at 80 DAT for $N_{180}P_{60}K_{40}$ and 0.245 at 40 DAT for control ($N_0P_0K_0$), respectively, were observed.

NDVI revealed clear effect of fertilizer response throughout the crop growing period in both the practices, puddle as well as unpuddled (Table 1). Table 1 showed that the plots treated with high nitrogenous fertilizer have more values of NDVI over control plots throughout the crop period. These figures revealed that maximum value of NDVI in control plots was observed at 70 DAT, which

Table 3 : Band ratio changes with different growth stages of unpuddled rice (grown in the year 1999) using different fertilizer treatments

Treatments	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT	90 DAT	100 DAT	110 DAT
$N_0P_0K_0$	2.445	3.474	5.517	9.420	7.600	5.937	4.120	2.710
$N_0P_{60}K_0$	2.512	3.680	5.710	9.600	7.930	5.804	4.430	2.806
$N_0P_0K_{40}$	2.800	3.620	5.667	9.520	7.830	6.424	4.815	3.019
$N_0P_{60}K_{40}$	3.480	3.632	6.355	10.000	8.230	6.589	5.114	3.290
$N_{40}P_0K_0$	2.850	4.401	6.429	8.988	10.277	6.882	5.187	4.022
$N_{40}P_{60}K_0$	3.317	4.938	6.462	9.408	10.452	7.123	5.014	4.248
$N_{40}P_0K_{40}$	4.204	4.866	6.594	9.534	10.361	7.330	5.094	4.443
$N_{40}P_{60}K_{40}$	4.260	5.014	6.801	9.540	10.523	7.332	5.444	4.502
$N_{80}P_0K_0$	3.672	4.428	6.856	9.626	10.642	7.433	5.467	4.592
$N_{80}P_{60}K_0$	3.915	5.372	6.875	9.843	10.658	7.490	5.365	4.623
$N_{80}P_0K_{40}$	4.318	5.231	6.899	9.926	10.666	7.439	5.229	4.594
$N_{80}P_{60}K_{40}$	4.500	5.418	7.067	10.177	10.971	7.834	5.731	4.650
$N_{120}P_0K_0$	3.718	5.360	7.127	10.261	11.201	7.872	5.562	4.699
$N_{120}P_{60}K_0$	4.315	5.677	7.744	10.470	11.345	7.886	5.800	4.753
$N_{120}P_0K_{40}$	4.666	5.612	7.831	10.301	11.476	8.171	5.801	4.730
$N_{120}P_{60}K_{40}$	4.044	6.152	8.182	10.860	11.642	8.436	6.258	4.931

Table 4 : Band ratio changes with different growth stages of puddle and unpuddled rice (grown in the year 2001) using different fertilizer treatments

Treatments	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT	90 DAT	100 DAT	110 DAT
Puddled rice								
$N_0P_0K_0$	2.722	4.014	6.840	9.070	8.510	6.414	4.612	2.598
$N_{80}P_{60}K_{40}$	2.863	4.222	7.475	9.470	9.600	7.300	5.087	3.393
$N_{120}P_{60}K_{40}$	3.013	4.517	8.153	10.714	10.911	7.980	5.737	3.830
$N_{180}P_{60}K_{40}$	3.245	4.980	8.745	10.978	11.748	9.600	6.865	4.350
Unpuddled rice								
$N_0P_0K_0$	1.934	2.965	5.130	6.579	6.190	4.106	3.246	2.075
$N_{80}P_{60}K_{40}$	2.132	3.286	5.854	7.410	7.330	5.085	3.956	2.259
$N_{120}P_{60}K_{40}$	2.389	3.536	6.590	8.012	8.895	6.128	4.549	2.562
$N_{180}P_{60}K_{40}$	2.627	4.288	7.448	8.853	9.837	7.687	4.867	2.958

Table 5 : Comparison of co-efficient of determination (R^2) of the crop biometrics with vegetation indices for the rice crop

Parameters	Puddled rice				Unpuddled rice			
	NDVI		Band ratio		NDVI		Band ratio	
	1999	2001	1999	2001	1999	2001	1999	2001
Total chlorophyll	0.79	0.78	0.84	0.83	0.78	0.77	0.79	0.82
Dry matter	0.73	0.67	0.75	0.68	0.70	0.71	0.74	0.66
LAI	0.75	0.70	0.78	0.78	0.75	0.68	0.78	0.77

is 10 days earlier than $N_{180}P_{60}K_{40}$ fertilized plots because without fertilizers plots achieved early senescence.

Effects of nitrogen and tillage have been analyzed using SAS (1998) software to test the significance level of each parameter by calculating multiple factor ANOVA. Effect of nitrogen and tillage *viz*., puddled and unpuddled, were found to be highly correlated for NDVI at peak growth stage (80 DAT). Nitrogen was significant at 1 per cent level of probability for almost all growth stages. Similarly, tillage was also found to be highly correlated for all growth stages except 60 DAT.

Band ratio (also called Ratio Vegetation Index) revealed the increasing trend of value up to milking stage (80 DAT) of rice crop in puddled and unpuddled treatments, thereafter the trend was found reversed (Table 2, 3 and 4). The maximum value of BR during first crop was 13.619 which found in $N_{120}P_{60}K_{40}$ fertilizer dose at 80 DAT and 11.748 in $N_{180}P_{60}K_{40}$ dose of fertilizer during second year of crop at 80 DAT in puddled rice whereas minimum values in the same tillage practice (puddled) were 1.963 at 40 DAT for $N_{40}P_0K_0$ and 2.598 at 110 DAT for control ($N_0P_0K_0$) during both the years, respectively (Table 2, 3 and 4). Unpuddled rice always showed the lower value of BR compared to puddled rice (Table 2 and 3). During first year of crop the maximum value were observed 11.642 at 80 DAT for $N_{120}P_{60}K_{40}$ fertilizer dose and 9.837 at 80 DAT for $N_{180}P_{60}K_{40}$ fertilizer dose during second crop for the unpuddled rice whereas minimum values of BR in the same tillage practice (unpuddled) were 2.445 and 1.934 in respective years of crop which were found at 40 DAT for controlled ($N_0P_0K_0$) plots in both crops. Higher dose of fertilizer contributed to higher value of BR, whereas lower values were observed in case of controlled (0 kg N/ha) and nitrogen deficit (40 or 80 kg N/ha) plots.

Recommended fertilizer dose (120:60:40::N:P:K) can also be compared with controlled plots. Fertilized plots were observed to have a higher value of BR than controlled ones throughout the crop growth period, both in puddled and unpuddled treatments.

Band ratio observed in puddled rice was higher in value than in unpuddled rice at peak growth stage (80 DAT) (Table 1) because puddling contributed to healthy crop canopy geometry and hence, had higher influence on spectral reflectance characteristics. Bajpai and Tripathi (2000) found the higher vegetation and canopy geometry in puddled rice compared to unpuddled rice, because of increasing soil water holding capacity due to reduced hydraulic conductivity.

Co-efficient of determination (Table 5) showed highest value (0.84) for band ratio verses chlorophyll content. In general, band ratio showed more value than NDVI if correlated with LAI, DM and chlorophyll content. Same trend of increasing or decreasing value was followed for both the indices irrespective of years of crop growth.

Polynomial second order equations of band ratio were found to be better fitted than NDVI with crop biometrics.

Chlorophyll contents, yield and seed quality of rice were affected by nitrogen fertilizer. Nitrogen application results in an increment in chlorophyll content (Gopal *et al.*, 1999; Jago and Curran, 1995 and Jain *et al*., 1999). Pandey *et al.* (2000) revealed that higher nitrogen dose (150 kg/ha) yielded higher grain biomass than comparatively lower dose (120kg/ha). Basal urea incorporation into soil without standing water gave significantly higher paddy yield than same amount of urea incorporated in 5 cm of standing water in both wet land preparation methods, puddled as well as in unpuddled (Jamil *et al*., 1992).

Literature Cited

Allen, W.A. and Richardson, A.J. (1986). Interaction of light with a plant canopy. *J. Optical Soc. America*, **58**: 1023-1028.

Aparicio, N., Villegas, D., Casadesus, J., Araus, J.L. and Royo, C. (2000). Spectral vegetation indices as non-destructive tool for determining durum wheat yield. *Agron. J.*, **92** (1): 83-91.

Bajpai, R.K. and Tripathi, R.P. (2000). Evaluation of non-puddling under shadow water tables and alternative tillage methods as soil and crop parameters in a rice-wheat system in Uttar Pradesh. *Soil Tillage Res.*, **55** (1-2): 99-101.

Birth, G.S. and McVey, G.R. (1968). Measuring the colour of turf with a spectrophotometer. *Agron, J.*, **60**: 640-643.

Field, C.B., Gamon, J.A. and Pnuelas, J. (1993). Remote sensing of terrestrial photosynthesis. In: *Ecophysiology of photosynthesis* (Eds ED Schulze and MM Caldwell), *Ecological Studies*, 100.

Gilabert, M.A., Gandia, S. and Melia, J. (1996). Analysis of spectral biophysical relationships for a corn canopy. *Remote Sens. Environ.*, **55**: 11-20.

Gopal, M., Devi, K.R. and Lingam, B. (1999). Effect of seeding density, level and time of N applicationin direct sown rice under puddle contions. *J. Res. ANGRAU*, **27** (1-2): 53-55.

Goward, S.N., Tucker, C.J. and Dye, D.G. (1985). North American vegetation patterns observed with NOAA-7 advanced very highresolution radiometer. *Vegetatio,* **64**:3-14.

Hiscox, J.D. and Israelstam, G.F. (1979). Amethod for the extraction of chlorophyll from leaf tissue without maceration *Can. J. Bot.,* **57**: 1332-1334.

Jago, R.A. and Curran, P.J. (1995). The effect of land contamination on the relationship between the red edge and chlorophyll concentration of a grass and canopy. In *RSS95: Remote Sensing in Action*, Nottingham: Remote Sensing Society, 442-449pp.

Jain, V., Pal, M., Lakkineni, K.C. and Abrol, Y.P. (1999). Photosynthetic characteristics in two wheat genotypes as affected by nitrogen nutrition. *Biologia. Plantarum,* **42** (2): 217-222.

Jamil, M., Shah, I.A., Mehdi, S.M. and Ismat, N. (1992). Effect of land preparation methods and fertilizer application on fertilizer use efficiency in rice KS 282. *J Agric. Res. (Pak),* **30** (4): 469-477.

Lin, X.Z., Huang, Q.M. and Tu, Z.P. (1990). Studies on high yield cultivation of rice in Guangdong by controlling chlorophyll content and leaf area index. *Jiangsu. J. Agric. Sci.,* **6**: 20-26.

Pandey, P.K., Pandey, M.D., Singh, Raghvendra and Singh, R. (2000). Response of medium land rice to sowing methods, moisture regimes and nitrogen levels. *Crop Res.,* **1** (2):249-252.

Rao, M.V. (1982). Wheat production problems in India. Proc. National seminar on productivity in wheat and wheat products, held in Vigyan Bhawan, New Delhi, April 29-30, pp. 5-9.

Rouse, J.W., Haas, R.H., Schell, J.A. and Deering, D.W. (1973). Monitoring vegetation systems in the great plains with ETRS. In : *Third ETRS Symp NASA Sp,* **357**(1) : 309-317.

Sader, R., Pedroso, P.A.C., Epifania, L.C., Gavioli, E.A. and Mattos Junior, D. (1990). Effects of nitrogen fertilizer on chlorophyll contents, yield and seed quality of rice. *Cientifica Jaboticabal,* **18** (2):63-69.

SAS (1998). *Statistical analysis system*/OR User's guide SAS Institute, NORTH CAROLINA, USA.

Sellers, P.J. (1987). Canopy reflectance, photosynthesis and transpiration. II The role of biophysics in the linearity of their interdependence. *Remote Sens. Environ.,* **6** : 143-183.

Srivastava, S.K., Nageswara, Rao, P.P. and Jayaraman, V. (1998). Towards space borne terrestrial imaging spectrometry. *Scientific Report ISRO-NNRMS-SR*: 41-98.

Stutterheim, N.C. and Barbier, J.M. (1995). Growth and yield formation of irrigated, direct seeded rice as affected by nitrogen fertilizer. *European J. Agron.,* **4** (3): 299-308.

Wang, K., Shen Zhang Quan, Wang, K., Shen, Z.Q. and Wang, R.C. (1998). Effect of nitrogen nutrition on the spectral characteristics of rice leaf and canopy. *Zhejiang Agric. Univ.,* **24** (1) : 93-97.

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